

# Endogenous Product Cycles

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## Product Cycles (Vernon 1966)

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- Innovation and initial production occurs the North (developed countries), close to large, high-income markets.
- After production methods become standardized, technology transfer or imitation shifts production to the South (developing countries) due to lower wages there.
- The North exports the latest, innovative goods in exchange for older, more established goods from the South.

## Product Cycle Model (Krugman 1979)

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- Exogenous Technological Change
  - New products are introduced in the North at an exogenous rate.
  - Southern firms become able to produce goods at an exogenous rate.
- Finds that relative wage paid to Northern labor (compared to Southern labor):
  - Increases in the rate of innovation relative to imitation,
  - Decreases in the relative size of the Northern labor supply.

## Endogenous Technological Change

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- Innovation: To be able to produce a new product, Northern entrepreneurs must expend resources.
  - Design good and perfect production techniques.
- Imitation: To be able to produce an existing product, Southern entrepreneurs must expend resources.
  - Engage in reverse engineering to learn about production processes developed in the North.

## Reward to Innovation

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- Since innovation involves costs, there must be enough reward to innovation success for innovation to occur, and similarly for imitation.
- The expected, present discounted value of profits earned acts as the reward to R&D.
- Successful innovators earn profits until imitation occurs.
- Successful imitators earn profits forever but magnitude shrinks over time.

## Structural Parameters

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- Since innovation and imitation endogenous, can look at effects on them of changing parameters:
  - Northern and Southern labor supplies,
  - Productivity of labor in innovation and imitation,
  - Policies such as tariffs and R&D subsidies.

## Consumers (Households)

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- Demand side is standard CES setup with symmetric differentiated products.
- Preferences for differentiated products identical across countries.
- Consumers seek to maximize time-separable intertemporal utility function.

$$U_i = \int_t^\infty e^{-\rho(\tau-t)} \log[u(\tau)] d\tau$$

- $\rho$  is subjective discount rate.

## Consumers (Households)

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- Instantaneous sub-utility function

$$u(\tau) = \left[ \int_0^n x(j)^\alpha dj \right]^{1/\alpha}$$

- $x(j)$  is consumption of product  $j$  ( $j$  is  $\omega$  in the article)
- $n$  is measure of varieties available at time  $\tau$ .

## Consumers (Households)

- Intertemporal budget constraint: present discounted value of expenditure cannot exceed that of income (plus initial assets).

$$\int_t^{\infty} e^{[R(\tau)-R(t)]} E(\tau) d\tau \leq A(t) + \int_t^{\infty} e^{[R(\tau)-R(t)]} Y(\tau) d\tau$$

- $R(t)$  is cumulative interest rate from time 0 to  $t$ ,
- $E(\tau)$  is spending and  $Y(\tau)$  factor income at time  $\tau$ ,
- $A(t)$  is value of initial asset holdings at time  $t$ .

## Consumers (Households)

- Intertemporal utility maximization requires

$$\dot{E} / E = \dot{R} - \rho$$

- Instantaneous utility maximization generates instantaneous demand for variety  $j$

$$x(j) = \frac{p(j)^{-\varepsilon}}{\int_0^n p(j')^{1-\varepsilon} dj'} E$$

- $p(j)$  is price of variety  $j$
- $\varepsilon = 1 / (1 - \alpha) > 1$  is the constant elasticity of substitution between every pair of products.

## Production

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- Single primary input is labor.
- Production of any variety requires  $a_x$  units of labor for each unit of output.
- Marginal cost is  $w_i a_x$  in county  $i$ .
  - $w_i$  is wage in country  $i$ .
- Producers behave as Bertrand competitors.
  - Take prices of other firms' products as given.

## Monopoly and Duopoly

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- Two Northern firms will never invent the same variety.
  - Would price at cost and earn no profits.
  - Must earn profits to offset innovation costs.
- Similarly, two Southern firms will never imitate the same variety.
- Each new variety starts as a monopoly.
  - Becomes a duopoly following imitation.

## Profit Maximization, Northern Firms

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- Consider a Northern firm that is the only firm able to produce a variety.
- Faces demand curve with constant elasticity  $-\epsilon$ .
- Profit-maximizing price is fixed markup over marginal cost.

$$p_N = \frac{w_N a_x}{\alpha}$$

## Profit Maximization, Southern Firms

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- Consider a Southern firm that is only firm that has imitated a variety.
  - Competes against Northern innovator of that variety.
- Two possible outcomes depending on the size of the gap between Northern and Southern wages.
  - Based on whether Northern innovator constrains price of Southern imitator.

## Pricing by Southern Firms

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- Wide gap case: If  $w_S < \alpha w_N$ , Southern firm can charge its monopoly price (markup over its costs) without fear of competition from Northern rival.

$$p_S = \frac{w_S a_x}{\alpha}$$

- Narrow gap case: Otherwise, Southern firm sets price equal to the cost of the Northern innovator.

$$p_S = w_N a_x$$

## R&D Learning Activities

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- When entrepreneur hires labor for innovation or imitation, derives
  - appropriable blueprint for producing a variety.
  - Non-appropriable additions to general knowledge.
- These knowledge spillovers enhance productivity of subsequent learning efforts within the country.

## Southern Imitation

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- Southern entrepreneurs chooses at random an existing product that not yet imitated.
- Must devote  $a_S/K_S$  units of labor to mastering the production process.
  - $a_S$  is productivity parameter for imitation ( $a_I$  in article).
  - $K_S = n_S$  is knowledge stock in the South, and is proportional to cumulative imitation experience.
  - $n_S$  is measure of imitated varieties.

## Northern Innovation

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- Northern entrepreneurs must devote  $a_N/K_N$  units of labor to mastering the production process.
  - $a_N$  is productivity parameter for innovation ( $a_D$  in article).
  - $K_N = n$  is knowledge stock in the North, and is proportional to cumulative innovation experience.
  - $n$  is measure of existing (innovated) varieties.

## R&D Valuation Conditions

- When imitation occurs in equilibrium, present-discounted value of Southern profits must equal the cost of imitation.

$$\int_t^{\infty} e^{-[R(\tau)-R(t)]} \pi_S(\tau) d\tau = w_S(t) a_S / n_S(t)$$

- When innovation occurs in equilibrium, present-discounted value of Northern profits must equal the cost of innovation.

## Labor Constraints

- Labor demand for innovation and production in the North cannot exceed Northern labor supply.

$$a_N \dot{n} / n + a_x n_N x_N = L_N$$

- Labor demand for imitation and production in the South cannot exceed Southern labor supply.

$$a_S \dot{n}_S / n_S + a_x n_S x_S = L_S$$

## Results for Wide Gap

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- Expansion in Northern labor supply or improvement in productivity of innovation does not affect innovation and imitation! Northern relative wage rises.
- Expansion in Southern labor supply or improvement in productivity of imitation increases innovation and imitation. Northern relative wage falls.
- If stronger intellectual property rights (IPR) protection increases difficulty of imitation, both imitation and innovation would fall.
- Ad valorem tariff or export subsidy by either country does not affect innovation or imitation!

## Results for Narrow Gap

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- Expansion in Northern labor supply or improvement in productivity of innovation increases innovation and decreases imitation. Northern relative wage rises.
- Expansion in Southern labor supply or improvement in productivity of imitation increases innovation and imitation. Northern relative wage falls.
- Again, if stronger intellectual property rights (IPR) protection increases difficulty of imitation, both imitation and innovation would fall.